ARL 148
PART II

A COMPARISON OF THE INFLUENCE OF MECHANICAL AND ACOUSTICAL VIBRATIONS ON FREE CONVECTION FROM A HORIZONTAL CYLINDER

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AERONAUTICAL RESEARCH LABORATORY
OFFICE OF AEROSPACE RESEARCH
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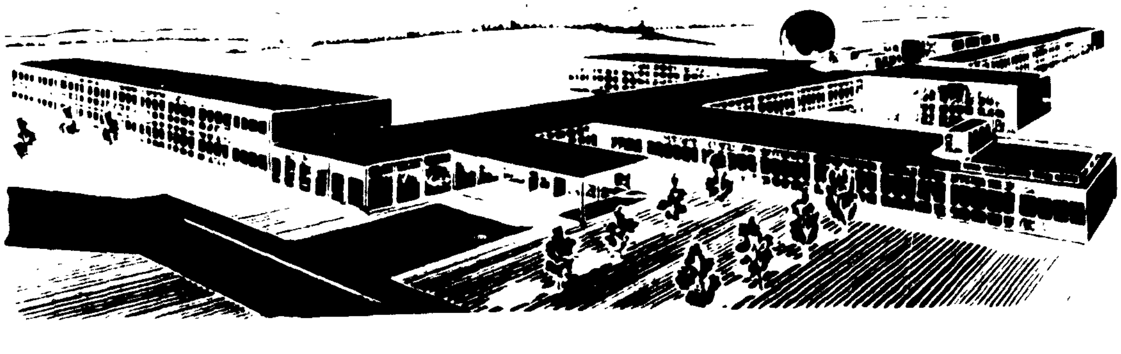

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OFFICE OF AEROSPACE RESEARCH
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FOREWORD

This final technical report was prepared by the Massachusetts Institute of Technology, Cambridge, Massachusetts, on Contract AF 33(616)-6076 for the Aeronautical Research Laboratory, Office of Aerospace Research, United States Air Force. The work reported herein was accomplished on Task 70138, "Research on a Novel Technique of Measuring Very High Temperature Gas" of Project 7064, "Research on Aerodynamic Fields", under the technical cognizance of Dr. Max G. Scherberg and Mr. Erich Soehngen of the Thermo-Mechanics Research Branch of ARL.

Part II is based, in part, on a S. M. and Nav. E. thesis entitled "The Influence of Mechanical Vibration on Free Convective Heat Transfer from Horizontal Cylinders" presented by E. M. Peebles to MIT in June, 1961. The work was performed in the Research Laboratory of Heat Transfer in Electronics at MIT.

ABSTRACT

Empirical correlation equations have been published in the past by means of which the rate of convective heat transfer can be computed for a heated horizontal cylinder subjected to vertical mechanical vibrations (frequency order of magnitude: 100 cps) and horizontal transverse acoustical vibrations (frequency order of magnitude: 1000 cps). Flow-visualization studies, using smoke as the indicating medium, have revealed that the boundary-layer flow about a heated horizontal cylinder subjected to vertical mechanical vibrations is different from the flow which occurs when such a cylinder is placed at the antinode of a transverse stationary horizontal sound field: in the former case, a wide zone of turbulence surrounds the cylinder; whereas, in the latter case, a type of boundary-layer flow, called thermoacoustic streaming, occurs.

This report presents the results of an experimental investigation of the influence of horizontal transverse mechanical vibrations (frequency order of magnitude: 100 cps) upon the rate of convective heat transfer from a horizontal cylinder. The results of the experiments are compared with earlier findings. It is shown that, in spite of a ten-fold difference in frequency (and amplitude), the heat-transfer correlation equation previously developed for horizontal acoustical vibrations is also valid for horizontal mechanical vibrations, and that the character of the boundary-layer flow is the same (thermoacoustic streaming) for these two cases.

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NOMENCLATURE

a	sinusoidal displacement amplitude of vibration
D_o	outside diameter of test cylinder
f	frequency of vibration
F	geometrical weighting factor defined in (2)
g	gravitational constant
Gr	Grashof number evaluated at t_f; $Gr = \frac{D_o^3 g \beta \Delta t}{\nu^2}$
h_o	coefficient of heat transfer in the absence of vibrations (free convection)
h_v	coefficient of heat transfer in the presence of vibrations
k	thermal conductivity
l	half wave length of sound
Nu	Nusselt number evaluated at t_f, $Nu = \frac{hD_o}{k}$
Pr	Prandtl number evaluated at t_f
Q_c	computed rate of heat transfer by free convection from test cylinder (Eq. 4)
Q_{cond}	rate of heat transfer by conduction from test cylinder to yoke
Q_{cv}	rate of heat transfer by convection from test cylinder in the presence of vibrations
Q_l	$Q_l = Q_{cond} + Q_u$
Q_r	computed rate of heat transfer by radiation from test cylinder

Q_t	total metered electrical power delivered to test cylinder
Q_u	rate of heat transfer other than by conduction to the yoke plus radiation and conduction from lateral surface of test cylinder
Re	vibration Reynolds number evaluated at t_f, $Re = \frac{D_o v}{\nu}$
SPL	sound pressure level (db, re 0.0002 microbar)
t_a	ambient temperature
t_f	mean film temperature, $t_f = \frac{t_s + t_a}{2}$
t_s	surface temperature of test cylinder
Δt	temperature potential of test cylinder, $\Delta t = t_s - t_a$
Δt_{hm}	temperature potential of heat meters
v	velocity amplitude of vibration
β	coefficient of volumetric expansion
ν	kinematic viscosity

INTRODUCTION

The influence of vibrations upon the rate of heat transfer by free convection from a heated surface can be investigated experimentally by two different methods. In the first method, the surface is held stationary and acoustic vibrations are established in the fluid medium surrounding the surface. In the second method, an oscillatory motion is impressed upon the surface itself, leaving the fluid environment otherwise undisturbed--this method generally employs a mechanical system which is caused to vibrate at its resonant frequency. Both the acoustical, or "sound method," and the "mechanical vibrations method" have the same basic objective: to create an oscillating <u>relative</u> <u>velocity</u> vector between a heated surface and a fluid medium. These methods have been used to study the interaction between vibrations and free convection for flat plates and cylinders, for different orientations of the vibration vector relative to these surfaces, for different ranges of amplitude and frequency of vibration, and for different magnitudes of the temperature potential. For practical reasons, the geometry which has been most intensively studied is that of a horizontal cylinder subjected to vibrations whose direction is normal (transverse) to the longitudinal axis of the cylinder.

The study of coupled vibrations and free convection from horizontal cylinders has uncovered a number of unexpected facts. In the first place, the magnitude of the increase in the rate of heat transfer which can be effected by the application of vibrations is considerably

larger than had been anticipated prior to these studies; in fact, so large are these increases, that it appears probable that vibrations can be profitably employed in certain industrial heat-transfer applications. Another important fact which has been deduced from experiments involving coupled vibrations and free convection from horizontal cylinders is that, for a given cylinder diameter and direction of vibration, the heat-transfer coefficient, h_v, is a function of a single vibrational parameter, namely, the intensity of vibration, defined as the product af. This fact greatly simplifies the correlation of data for a given geometry; however, the functional relationship between h_v and af is different for different geometries. Thus, for example, experiments with heated vibrating wires indicate that, for intense mechanical vibrations, h_v is a function of $(af)^2$--the same equation was found to hold whether the wires were vibrated horizontally or vertically. On the other hand, experiments with larger cylinders have shown that the functional relationship between h_v and af is different for the case of horizontal vibrations than for the case of vertical vibrations. A study utilizing horizontal acoustical vibrations (frequency order of magnitude: 1000 cps) has shown that for a cylinder, 3/4" in diameter, h_v is proportional to $(af)^{2/3}$, for af $\geq$ 0.7 ft/sec; another study, utilizing vertical mechanical vibrations (frequency order of magnitude: 100 cps), has shown that for a cylinder, 7/8" in diameter, h_v is proportional to (af), for af $\geq$ 0.9 ft/sec. Flow visualization studies have demonstrated that the character of the boundary-layer flow for the various geometries described above is different in each case.

The great variety of experimental results mentioned in the preceding discussion leads to the important observation that, for coupled vibrations and free convection from cylinders, results obtained for a particular geometry, or for a particular range of experimental variables, may not be grossly extrapolated--the phenomena involved are non-linear and their interaction under unexplored conditions cannot, in general, be predicted. Having made this observation, it now becomes apparent that the quantitative data which have appeared in the literature to date are of limited usefulness, because these data represent more-or-less isolated and unrelated experiments. In order to render these data more useful--both for practical purposes, and for the purpose of providing a physical basis upon which a mathematical model for coupled vibrations and free convection can be constructed--it is necessary to systematically tie together the existing diverse pieces of information, so that each piece is part of a coherent whole. At the present time, it appears that this objective can best be achieved by performing a few judiciously chosen experiments and comparing the results of these experiments with currently available data. The present work represents an effort in this direction.

SURVEY OF THE LITERATURE

The review of literature given here will be limited to a discussion of publications which deal specifically with the influence of vibrations upon free convection from horizontal cylinders; particular attention will be given to papers containing quantitative results. For a more comprehensive outline of the literature relating to the general

problem of the interaction between vibrations and convective heat transfer, the reader is referred to (3).

In 1938 Martinelli and Boelter[1] investigated the effect of vertical mechanical vibrations upon the rate of heat transfer from a horizontal tube immersed in a tank of water. The tube diameter was 3/4", the amplitude of the sinusoidal motion of the cylinder was from 0 to 0.10", the frequency range was 0 to 40 cps, and the range of the temperature potential, Δt, was from 8 to 45 deg F. It was found that the coefficient of heat transfer was unaffected by mechanical vibrations for low vibration Reynolds numbers; this result was attributed to the dominance of free convection in this range. For sufficiently intense vibrations, however, the coefficient of heat transfer was observed to increase by as much as 400 per cent of its value without vibrations. No effort was made to observe the boundary-layer flow around the cylinder. The results of these experiments are plotted in Fig. 1. Unfortunately, the accuracy of these data is in doubt, since Boelter has reported that results obtained from a later experiment did not agree with the original data. In the Martinelli-Boelter apparatus, no provision was made to measure axial heat conduction from the test cylinder to its support structure. Since the rate of axial conduction must be known in order to determine accurately the rate of heat transfer by convection, it follows that the nondetermination of the conduction term is an important source of error in these experiments.

The influence of vibrations upon heat-transfer rates from horizontal heated wires to air has been investigated by Lemlich.[2]

In these experiments electrically heated wires of three different sizes (0.0253", 0.0396", and 0.0810" diameter) were vibrated with sinusoidal amplitudes up to 0.115" in the frequency range from 39 to 122 cps. The range of the temperature potential between the wires and the ambient air was 7 to 365 deg F. Increases in the heat-transfer coefficient were observed for increases in amplitude or in frequency. The coefficients of heat transfer for vibrating wires were as much as four times the coefficients without vibrations but with other conditions unaltered. For increases in heat transfer in excess of 10 per cent, Lemlich correlated his experimental data by the following empirical equation:

$$\frac{h_v}{h_o} = 0.75 + 0.0031 \frac{\overline{Re}^{2.05} \, (\beta \Delta t)^{0.33}}{(Gr\ Pr)^{0.41}} \tag{1}$$

where h_v is the heat-transfer coefficient with vibration, h_o the analogous coefficient without vibration; the Reynolds number, $\overline{Re}$, in the above equation was computed on the basis of the cylinder diameter and the average vibrational velocity, $\bar{v} = 4\ af$.

Lemlich reported similar results for both vertical and horizontal vibrations. In order to account for this observation, the concept of a "stretched film" surrounding the entire path of vibrations was proposed. An effort was made to observe the boundary-layer flow using smoke by holding a lighted cigarette under the heated wires. These smoke observations were inconclusive—it is probable that the high temperature and overwhelming size of the burning core of the cigarette relative to the wire caused convective currents of sufficient strength to conceal the effects sought.

Fand and Kaye[3] performed a quantitative experimental investigation of the influence of sound fields upon free convection from a horizontal cylinder in air. In these experiments the diameter of the cylinder was 3/4", and the vibration vector was perpendicular both to the axis of the cylinder and to the force of gravity. The results show that for stationary sound waves whose half-wave length was 6 or more times the diameter of the test cylinder ($l/D_o \geqq 6$), the coefficient of heat transfer is a function of only two variables: namely, the temperature potential and the intensity of vibration--the data for $l/D_o \geqq 6$ are given in Fig. 2. The lines at constant Δt in Fig. 2 show that a "critical sound pressure level" exists at approximately 140 db, below which the influence of sound upon the convective heat-transfer rate is negligible and above which the rate is markedly increased by sound. (Sound pressure levels expressed in db may be converted into units of af with the aid of Fig. 3.)

In order to gain insight into the physical mechanism which caused the rate of heat transfer to increase in the presence of intense sound, Fand and Kaye[4] performed a flow-visualization study, using smoke as the indicating medium. This study revealed that at the critical sound pressure level the typical free-convective boundary-layer flow pattern around the heated cylinder is disrupted, and a fundamentally different type of boundary-layer flow, called thermoacoustic streaming, develops. Thermoacoustic streaming is characterized by a pair of oscillating vortices which begin to appear above the upper surface of the test cylinder when the sound pressure level reaches the critical value. As the sound pressure level is increased beyond the critical value, the vortices eventually reach a stage of development wherein their character is fully established;

when this stage has been reached, further increase in the sound pressure level increases the size of the vortices but does not alter their form. Fig. 4 is a photograph in which the streamlines of free-convective flow about a heated horizontal cylinder are made visible by means of a series of smoke filaments issuing from a row of hypodermic needles; Fig. 5 is a similar photograph which shows fully-developed thermoacoustic vortex flow.

For $1/D_o \geqslant 6$ (see Fig. 2), Fand and Kaye found that the critical vibration intensity is 0.36 ft/sec (SPL = 140 db); the vibration intensity for fully-developed thermoacoustic streaming is 0.71 ft/sec (SPL = 146 db); and, for fully-developed thermoacoustic streaming, the heat-transfer coefficient may be determined from the following empirical correlation equation.

$$h_v = 0.722 \left[\Delta t \, (af)^2 \, F \right]^{1/3} \tag{2}$$

Since, for a simple harmonic wave, the velocity amplitude $v = 2\pi af$, it follows that the quantity $(af)^2$ which appears in Eq. 2 is proportional to the kinetic energy of the sound vibration. The factor F is a geometrical weighting factor defined and evaluated in (3); the numerical value of F approaches 1 as the ratio of half-wave length to cylinder diameter approaches infinity.

More recently, Fand and Kaye[5] have completed an experimental investigation of the influence of vertical mechanical vibrations on heat transfer by free convection from a horizontal cylinder. The diameter of the cylinder was 7/8", and the ranges of the primary experimental variables

were as follows: temperature potential, Δt, 25 to 185 deg F; amplitude of vibration, a, 0 to 0.16"; frequency of vibration, f, 54 to 225 cps; intensity of vibration, af, 0 to 1.22 ft/sec. The results, given in Fig. 6, show that in this case, too, the sole controlling vibrational variable is the intensity of vibration. For intensities of vibration less than 0.3 ft/sec, the influence of vibrations upon the coefficient of heat transfer is negligible; above this so-called "critical intensity," the effect of vibrations is to increase the heat-transfer coefficient significantly. A flow visualization study, employing smoke as the indicating medium, was carried out and indicated that the fluid-dynamical mechanism which causes the observed increases in the heat-transfer coefficient is vibrationally induced turbulence. This turbulent type of boundary-layer flow differs radically from the vortex type of flow, called thermoacoustic streaming, which develops near a horizontal cylinder in the presence of acoustically induced transverse horizontal vibrations.

The lines for constant Δt in Fig. 6 show that in the experimental region defined by $\Delta t < 100$ deg F, the heat-transfer coefficient is independent of Δt for sufficiently high levels of vibrations. In the region defined by $\Delta t \geqslant 100$ deg F and af $\geqslant 0.9$ ft/sec, the following empirical equation applies:

$$h_v = 0.847 \left(\frac{\Delta t}{D_o}\right)^{0.2} (af) \qquad (3)$$

It is of interest to note that the velocity amplitude, v, for a simple harmonic oscillation is given by $v = 2\pi af$, from which it follows that the heat-transfer coefficient in Eq. 3 is directly proportional to the velocity of vibration.

APPARATUS

The apparatus used in this study consisted basically of an electrically heated circular test cylinder, instrumented to provide convective heat-transfer data, and a vibrating system to which the test cylinder was fastened by means of a yoke. Heat meters were interposed between the test cylinder and the clamps of the yoke, in order to measure the rate of heat transfer by conduction from the test cylinder to its support structure.

The test cylinder, 7/8" OD, consisted of an aluminum sleeve which contained an electric resistance heater wound on a spirally grooved ceramic base as shown in detail in Fig. 7. Eight thermocouples were embedded in the surface of the test cylinder at sections A-A through G-G; the arithmetic mean of the readings of the six thermocouples at sections B-B through F-F was defined as the cylinder surface temperature, t_s.

The heat meters, shown in Fig. 7, consisted of two thin copper rings separated by a teflon spacer. Differential thermocouples were soldered to the copper rings, thereby providing a means by which the temperature drop across the teflon spacers could be measured. Since all heat conducted from the test cylinder to its support structure must pass through the teflon spacers, and since this conduction loss depends upon the temperature difference across the spacers, it follows that the readings of the differential thermocouples provide a measure of the conduction loss. The relationship between the conduction loss (plus certain small additional losses) and the temperature difference across the teflon

spacers was obtained from a series of calibration tests described in greater detail in the next section.

The vibrating system consisted of two beams and an electromechanical vibrator, as shown in Fig. 8. One beam, in the form of a heavy machined channel, was securely bolted to the vibrator and served as an alignment platform upon which the second beam, called the "resonant beam" was mounted by means of two hinged supports. The resonant beam, to which the yoke was clamped at midspan, was made to vibrate as a "free-free" beam, by driving it with the electromechanical exciter at its fundamental resonant frequency (104 cps); in order to achieve the "free-free" condition, the hinged supports of the resonant beam were located at the nodal points. The frequency of vibration was measured with an electronic frequency counter, correct to within 1 cps; the amplitude of vibration was measured by means of a cathetometer with an accuracy of 0.002". The test stand was designed so that the entire apparatus could be rotated through 90 deg. Fig. 8 is a drawing of the apparatus in the vertical position. Fig. 9a is a close-up photograph of the apparatus in the vertical position, and Fig. 9b is a photograph of the apparatus in the horizontal testing position employed in the present investigation.

EXPERIMENTAI PROCEDURE AND RESULTS

Three series of heat-transfer tests were performed, one with free-convection (no vibrations) and two with the cylinder executing horizontal transverse vibrations. The purpose of the free-convection tests was to obtain calibration data relating the heat conduction loss from the test cylinder, plus certain small additional heat losses described

below, with the temperature difference across the heat meters. A calibration curve was constructed by plotting $(Q_t - Q_r - Q_c)$ versus Δt_{hm}, where Q_t represents measured rates of electrical energy delivered to the test cylinder, and Δt_{hm} represents corresponding measured steady-state temperature differences across the heat meters; Q_r represents the rate of heat transfer by radiation from the cylinder surface, computed by conventional methods; and Q_c represents the rate of heat transfer by free convection, computed from the following empirical formula:(5)

$$h_o = 0.255 \left(\frac{\Delta t}{D_o}\right)^{\frac{1}{4}} \tag{4}$$

The quantity $(Q_t - Q_r - Q_c)$ is equal to the conduction loss, Q_{cond}, from the test cylinder to the yoke, plus certain small losses, Q_u, which cannot be accounted for quantitatively; these unaccountable losses include convection losses from the ends of the cylinder and from the exposed surfaces of the heat meters, and also conduction losses through electrical lead wires. Thus, the calibration curve which was obtained consisted of a plot of $Q_l = (Q_{cond} + Q_u)$ versus Δt_{hm}, where Q_l represents all heat transfer from the test cylinder other than radiation and free convection from its lateral surface. Since the values of Q_u were relatively small, it was assumed that the change in Q_u due to vibrations would be negligible; therefore, the calibration curve, Q_l vs. Δt_{hm}, obtained in the absence of vibrations, was used to determine the losses in all subsequent tests in which vibrations were present.

Two series of heat-transfer tests were performed utilizing various vibrational intensities in the range between 0.21 and 1.12 ft/sec;

in the first series, the electrical input to the test cylinder, Q_t, was adjusted until the steady-state temperature potential, Δt, equaled 150 ± 1 deg F; in the second series, the electrical input was adjusted until the steady-state temperature potential, Δt, equaled 50 ± 1 deg F. In each heat-transfer test involving vibrations, the steady-state reading of Δt_{hm} was recorded, and the corresponding value of Q_l was obtained from the calibration curve. The convective rate of heat transfer from the vibrating cylinder, Q_{cv}, was then computed by subtracting the losses, Q_l, and the computed rate of radiation, Q_r, from Q_t. The heat-transfer coefficient in the presence of vibrations, h_v, was then determined from Q_{cv} by using the defining equation. The results of both series of heat-transfer tests in the presence of vibrations are plotted in Fig. 10.

In order to observe the character of the boundary-layer flow around the heated test cylinder in the presence of horizontal vibrations, a photographic flow-visualization study, employing smoke as the indicating medium, was performed. Unfortunately, the photographs obtained are not of printable quality; however, it was observed that the boundary-layer flow in the presence of vibrations closely resembled the kind of vortex flow shown in Fig. 5.

DISCUSSION OF RESULTS AND CONCLUSIONS

The experimental results of the present investigation, plotted in Fig. 10, were compared with all pertinent published data. It was found that the quantitative and qualitative (flow visualization) results obtained here were in close agreement with the data for coupled heat transfer and sound published in (2). In order to facilitate the comparison of the

quantitative results, appropriate constant-Δt lines taken from (2) have been included in Fig. 10. The close agreement between the quantitative data and flow-visualization studies of the present investigation with the results of the study employing sound leads to the following conclusions:

1. The physical mechanism of interaction between free-convection from a heated horizontal cylinder and horizontal transverse vibrations is essentially the same, whether the vibrations are acoustically (for $l/D_o \geq 6$) or mechanically induced. This conclusion agrees with predictions based on theory made by Westervelt[6] and Lighthill[7].

2. The critical intensity, above which the rate of heat transfer from a heated horizontal cylinder increases significantly, is approximately 0.36 ft/sec. The critical intensity is not a function of the frequency of vibration as predicted by Westervelt[8].

3. For values of $af \geq 0.7$ ft/sec., Eq. 2 may be used to compute the rate of heat transfer from a heated horizontal cylinder subjected to either acoustically or mechanically induced horizontal transverse vibrations.

In order to fully and properly interpret the preceding conclusions, it is necessary to discuss an additional variable which is implicit in all the experiments described above: This variable is the ratio of the amplitude of vibration to the diameter of the cylinder, a/D_o. The ratio a/D_o is an important parameter in all fluid-dynamical problems involving transversely vibrating cylinders[9]. The wide divergence between Eq. 1 and Eq. 2, both of which apply to horizontal heated cylinders subjected to horizontal transverse vibrations, is attributable to the large difference between the values of a/D_o in the two experiments to which these

equations refer--in Lemlich's work with wires (Eq. 1), $a/D_o \sim 4$; whereas, in Fand and Kaye's sound experiments (Eq. 2), $a/D_o \sim 0.016$. In the present investigation, $a/D_o \sim 0.16$; therefore, it may be concluded that Eq. 2 holds in spite of a tenfold increase in a/D_o. This experimental demonstration of the insensitivity of the coupling between free convection and vibrations to changes in a/D_o over a relatively large range of values may simplify the analytical formulation of this complex problem. The extension of the range of applicability of Eq. 2 is useful from a practical point of view, because the equation may now be applied with confidence to numerous additional cases of practical interest.

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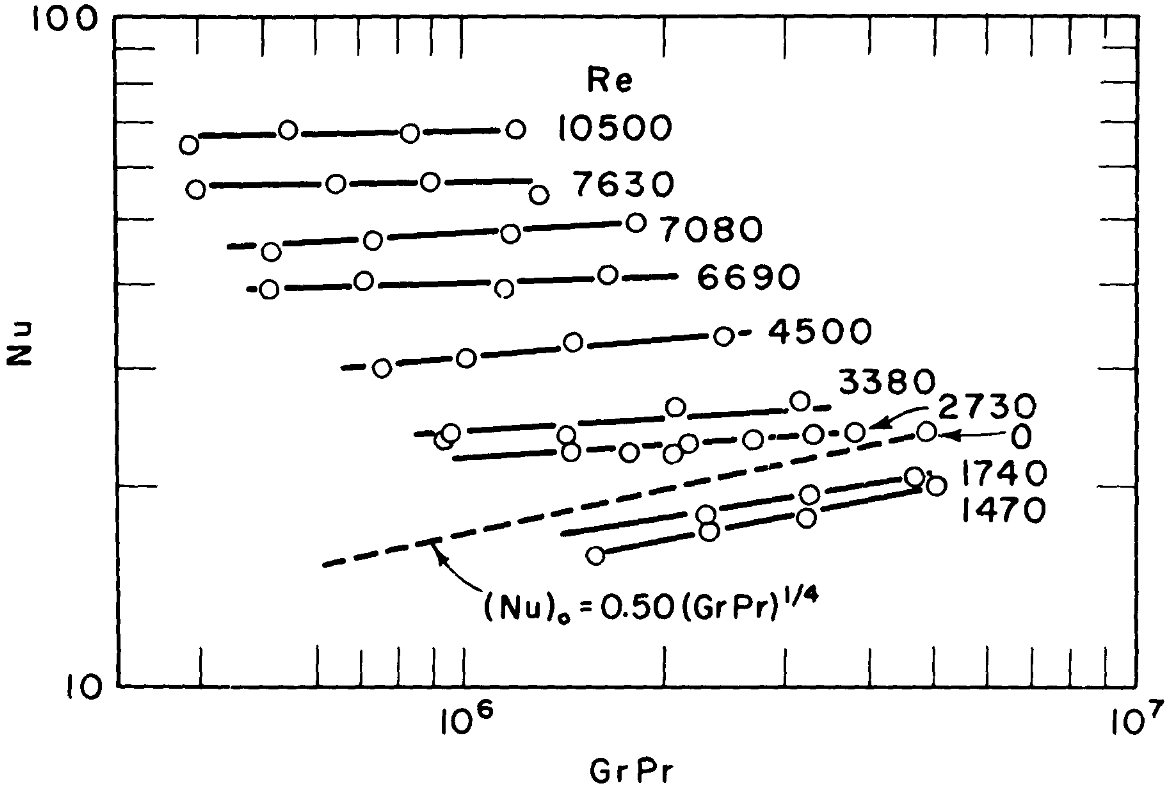

Figure 1. Data of Martinelli and Boelter for Vertical Vibrations of a Horizontal Cylinder in Water.

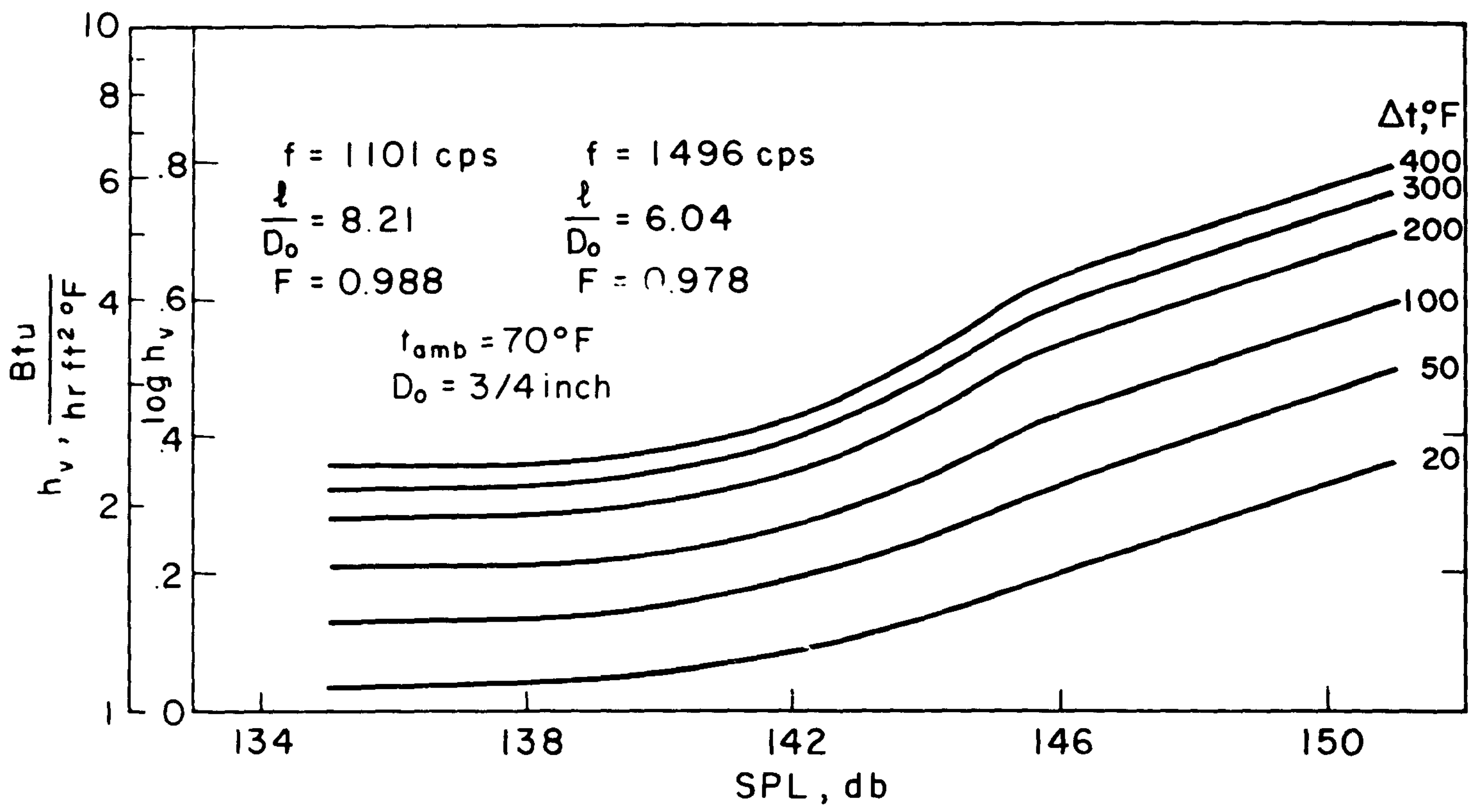

Figure 2. Data of Fand and Kaye for Convective Heat Transfer from a Heated Horizontal Cylinder in the Presence of an Intense Sound Field in Air.

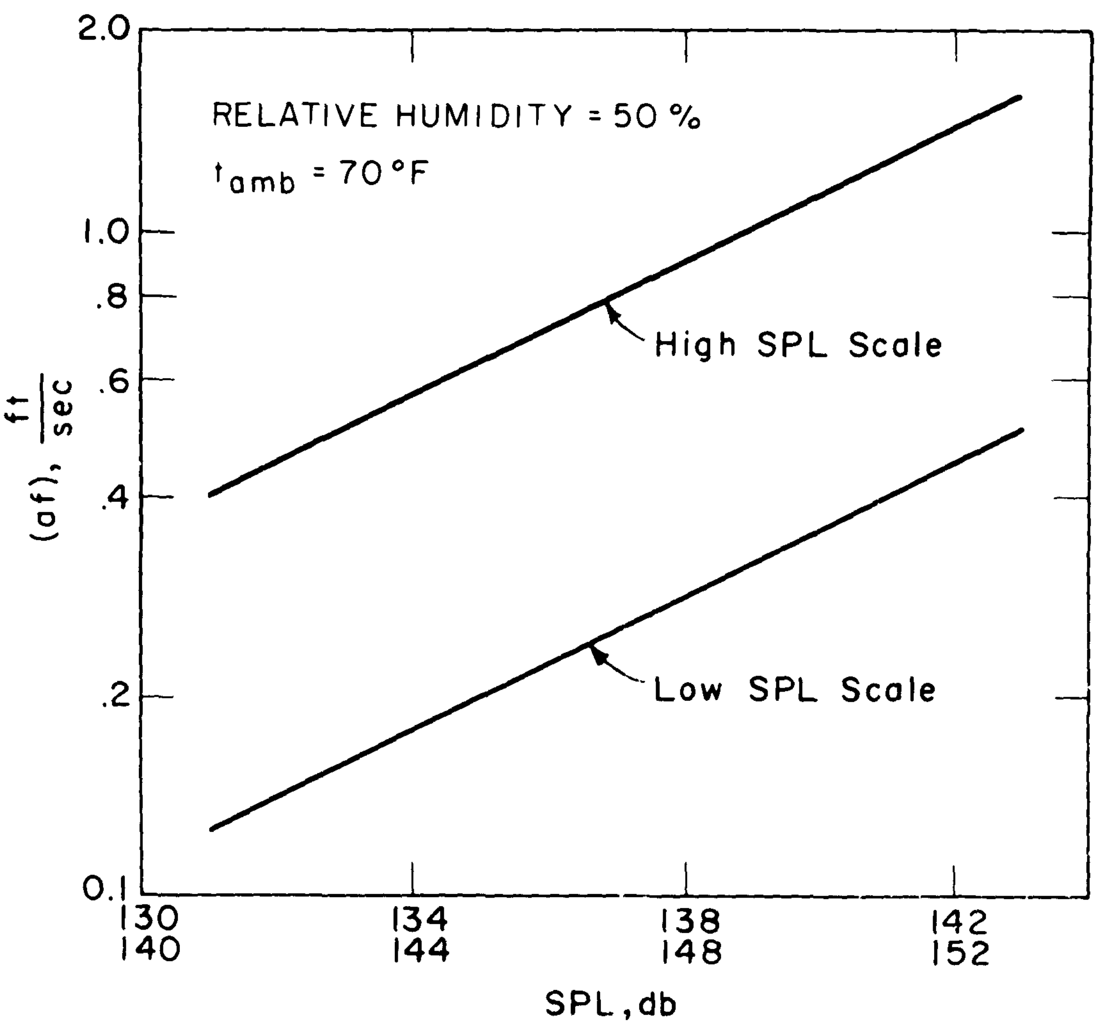

Figure 3. Conversion of SPL to af

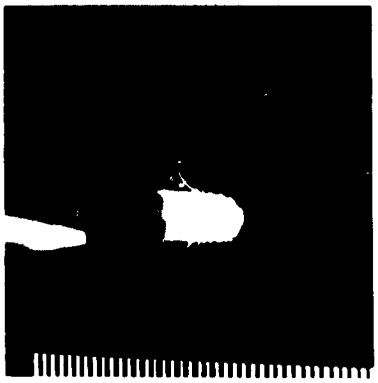

Fig. 4 Free Convection: Δt = 200 $^{\circ}$F

Fig. 5 Thermoacoustic Streaming:
f = 1100 cps, SPL = 148 db, Δt = 200 $^{\circ}$F

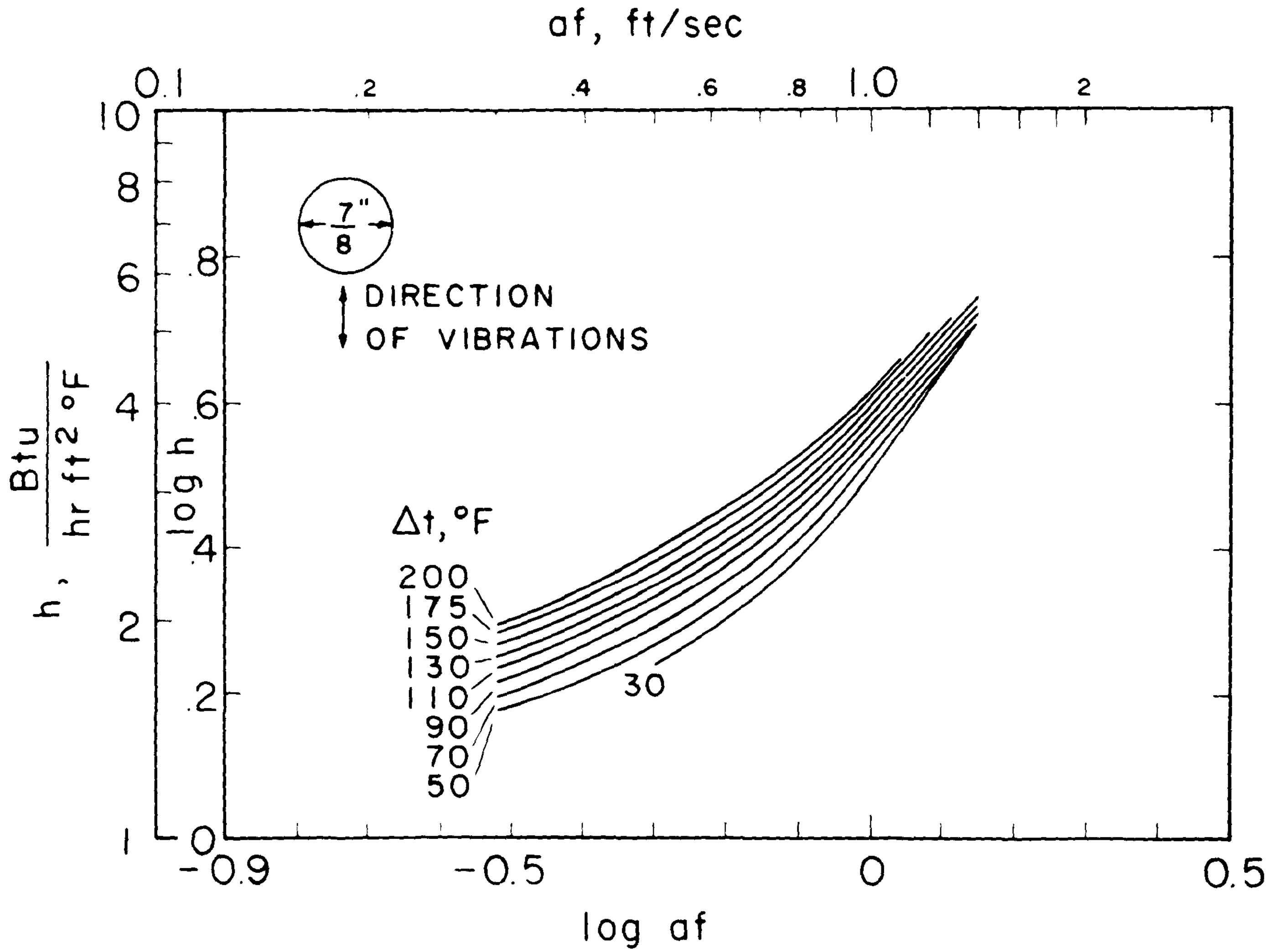

Figure 6. Data of Fand and Kaye for Vertical Vibrations of a Horizontal Cylinder in Air.

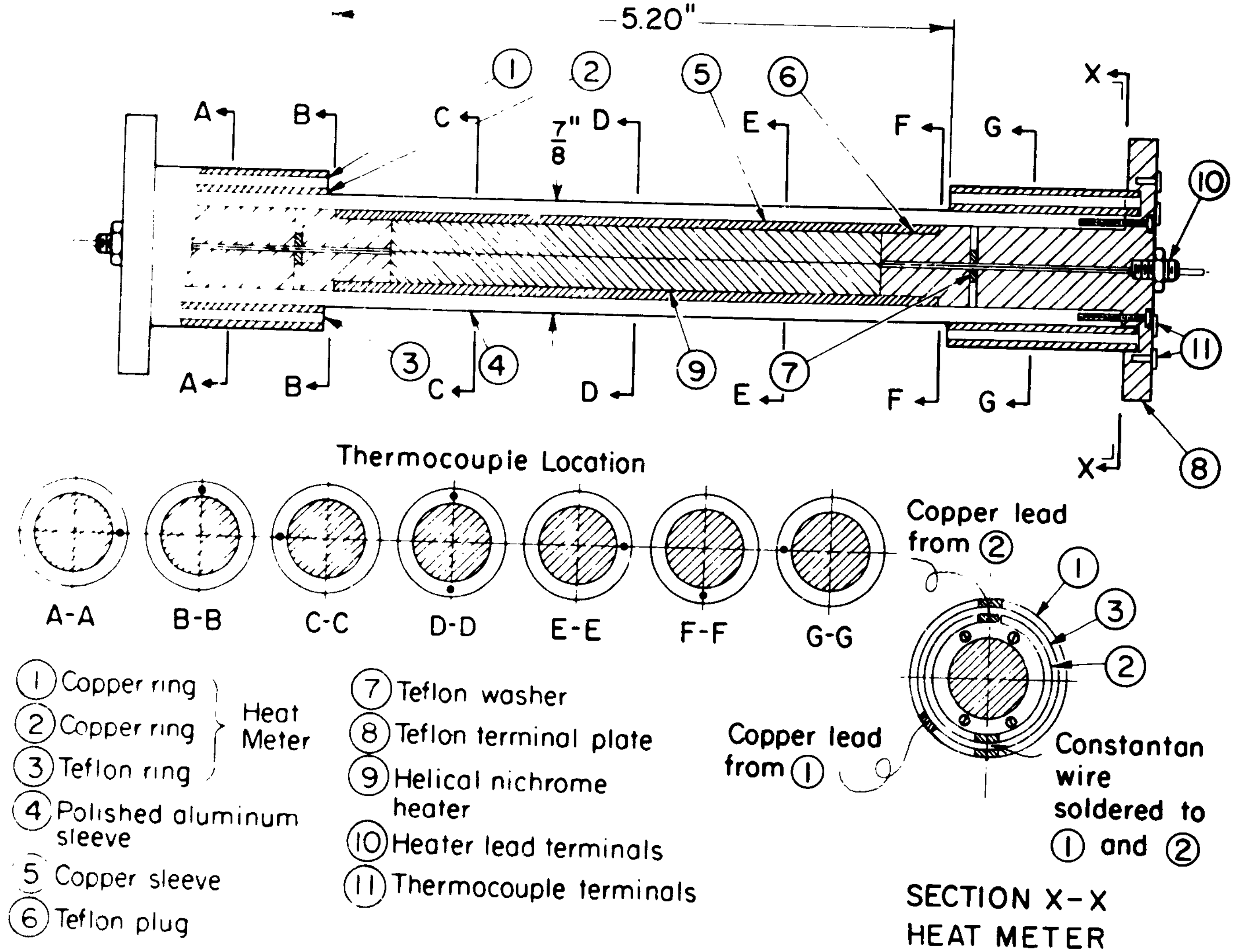

Figure 7. Test Cylinder.

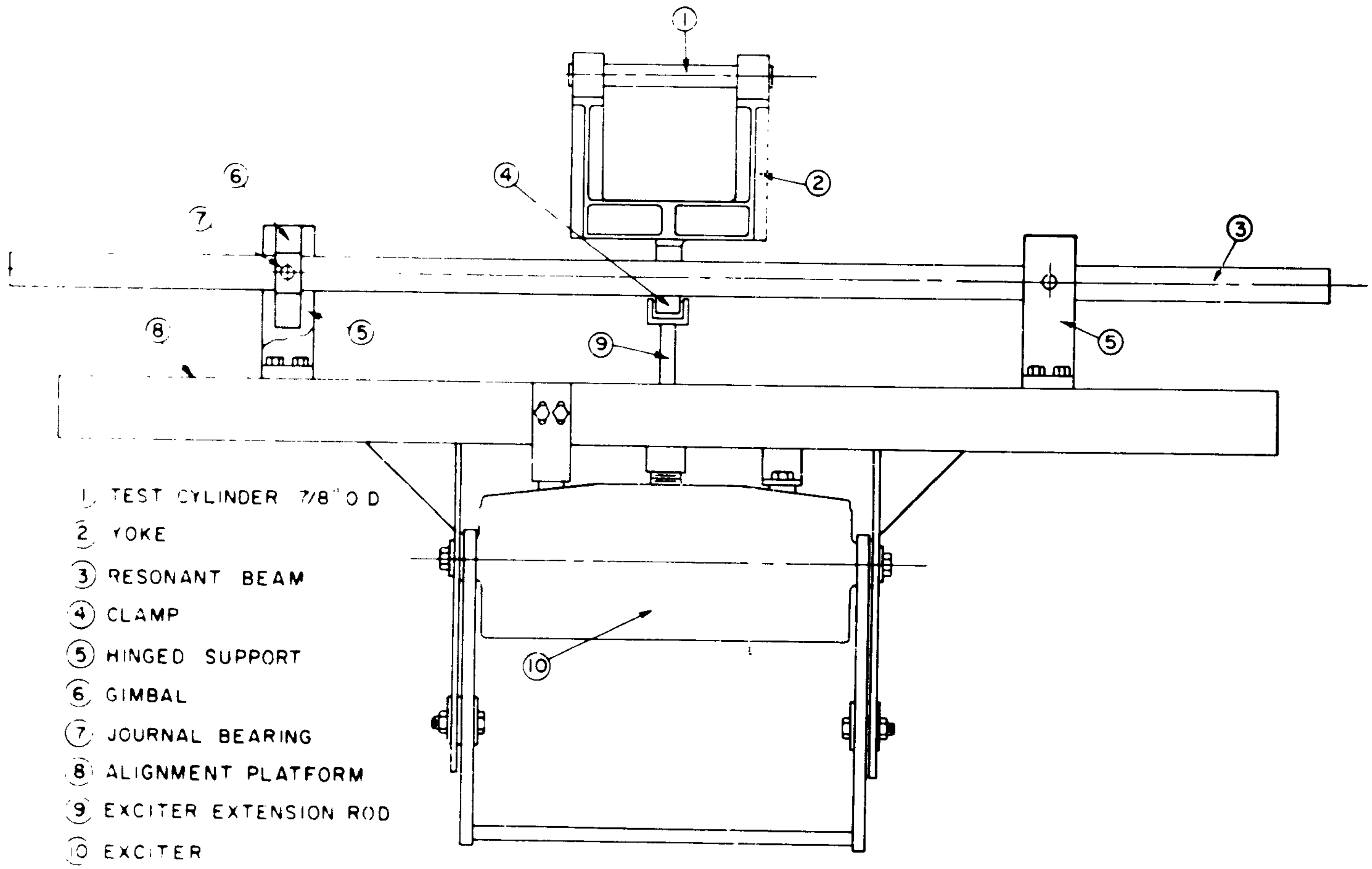

Figure 8. Vibration Test Stand.

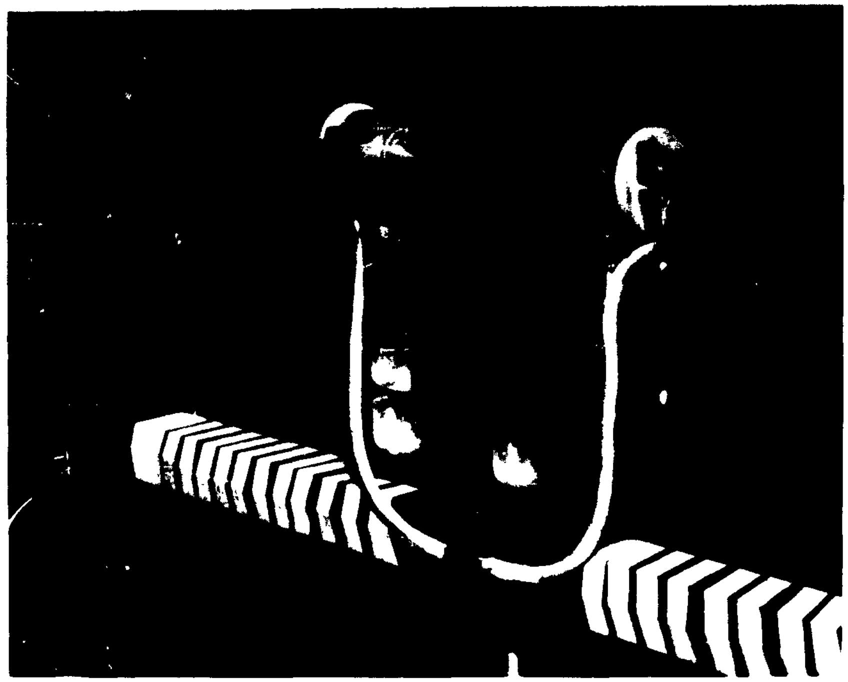

Figure 9a. Close-up of Photograph Apparatus

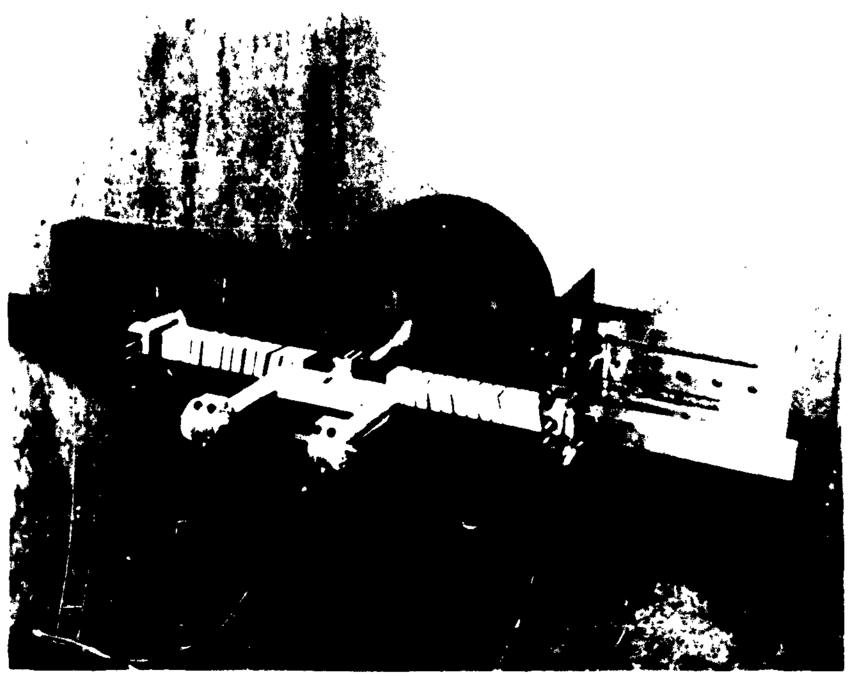

Figure 9b. Photograph of Apparatus in Horizontal Test Position.

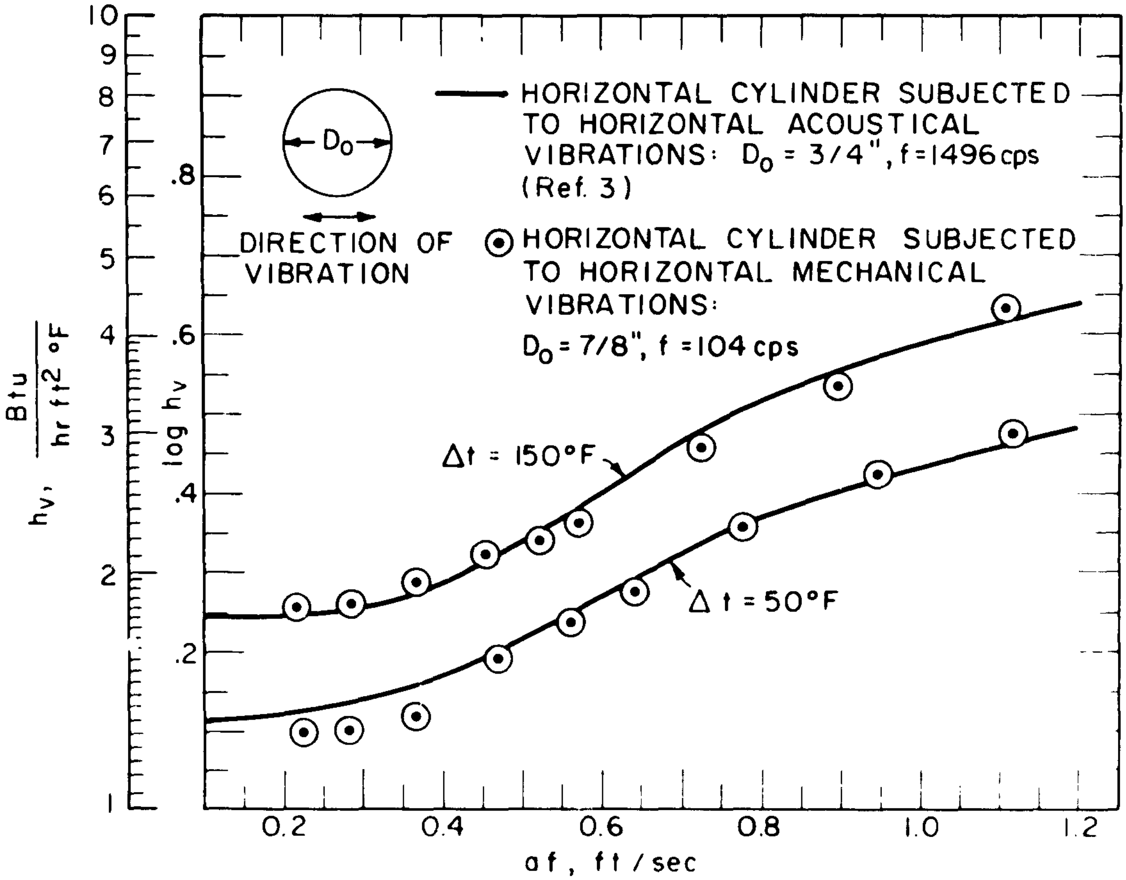

Figure 10. Comparison of h_v vs af at Constant Δt for Horizontal Heated Cylinder Subjected to MEchanical and Acoustical Vibrations in Air.

Massachusetts Institute of Technology, Cambridge, Mass., A COMPARISON OF THE INFLUENCE OF MECHANICAL AND ACOUSTICAL VIBRATIONS ON FREE CONVECTION FROM A HORIZONTAL CYLINDER, by R. M. Fand, E. M. Peebles, December 1961, 25 p. (Project 7064; Task 70138) (Contract AF 33(616)-6976) ARL 148, Part II.

Unclassified Report

Empirical Correlation Equations have been published in the past by means of which the rate of convective heat transfer can be computed for a heated horizontal cylinder subjected to vertical mechanical vibrations (frequency order of magnitude: 100 cps) and horizontal transvers e acoustical vibrations (frequency order of magnitude: 1000 cps). Flow-visualization studies, using smoke as the indicating medium, have revealed that the

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This report presents the results of an experimental investigation of the influence of horizontal transverse mechanical vibrations (frequency order of magnitude: 100 cps) upon the rate of convective heat transfer from a horizontal cylinder. The results of the experiments are compared with earlier findings.

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